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New dreams for old

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IN 1964, New Scientist commissioned nearly a hundred internationally known experts to peer into the future and guess the real shape of that fateful year, 1984. Not an easy task, one might think, yet some of them managed to predict the developments of the next twenty years with positively Dephic accuracy. Others were more than a little off beam. The pattern that emerges is that many of the physicists were too optimistic about advances in their field while the biologist underestimated the rate of progress. Thirty years on, we invited eight of those experts to review their predictions and, if they dared, to make new ones for the future

Professor Joshua Lederberg, Rockefeller University, New York.

The predictions for 1984:

Successful organ transplants creating a need for moral guidelines to control the market in donor organs.

Artificial prosthetic organs.

Increased life expectancy.

Modification of the human brain through treatment of the fetus or infant.

Genetic cloning through nuclear transplantation, allowing us to predetermine sex in fetuses and avoid hereditary abnormalities.

The reality and the future:

Some thirty-one years ago, I referred to a "Crisis in Evolution" as a product of the scientific revolution eventuating in molecular biology. I stressed my preference for "euphenic" measures, those affecting the function and development of the individual, to "eugenic", which might leave a more deep-seated imprint on the evolution of the species. The time span for that muted prophecy is more than half up on a linear scale (albeit technological advance is more nearly exponential). It is reasonable to ask for an assessment.

There has been radical scientific advance in the first and fifth points - sufficient to have recruited substantial impetus for social regulation, for example, of "markets" in organs, and in research with human embryos respectively. I am confident that those markets will be alleviated by the development of transgenic animals, bred for the purpose: this is the target of several commercial initiatives right now. The technology for embryological interventions - the very transgenics just mentioned - is already far past the point of comfort about their human application. I have just seen a notice in the daily press advertising a service for single sperm inoculation with in vitro fertilisation, as a means to alleviate male infertility.

With the exception of the artificial heart, organ prostheses are moving along in many fields, with implants ranging from titanium teeth (which I enjoy to great advantage myself) to pacemakers and rudimentary artificial cochleas. There is social ambivalence about the heart, as much as daunting technical obstacles in the control of blood clotting: we have hardly begun to measure the open-ended costs that will be invoked by that technological fix. For sure, prevention of heart disease has been a preferred option during the past three decades, and one already with substantial benefit to healthy life span.

As to the brain, we have just begun to uncover the relevant range of neural growth factors; these are in earliest clinical trials, some of them disappointing, to determine the range of their therapeutic utility. A modest euphenic advance has been advocacy of folic acid supplementation for the avoidance of spina bifida. We are still in the midst of evolving the social technology needed to cope with the steady advance in life span: witness the debates about healthcare reform in the United States.

Infectious disease was hardly mentioned in 1964. We were riding the crest of optimism born of the successes of antibiotics and vaccines. And we were negligent of the unremitting problems of infection in the developing world. Not till later in the 1960s did I observe that such complacency could lead to the re-emergence of viral and of drug-resistant bacterial infections that constitute new plagues today. We have many intrinsically powerful tools to counter these threats, but only if we recognise the urgency of these problems and deploy our scientific skills against them.

Professor Avrion Mitchison, Scientific Director of the German Centre for Research into Rheumatism, Berlin.

The prediction for 1984:

Methods for synthesising cell products such as enzymes chemically, without having to rely on tissue cultures, will be advanced and may be used to treat metabolic diseases.

The reality and the future:

My 1964 predictions were about manufacture in tissue culture: how we were going to make hormones, antigens, antibodies and enzymes from cells grown outside the body. Looking back at them, they seem so totally obvious. Is it really possible that only thirty years ago we weren't already doing all that? How time does fly.

To mention just a few examples, the hormone erythropoietin is manufactured entirely in culture, on a large scale for treatment of kidney patients who are on dialysis. It has made the fortune of the American company Amgen. Rabies antigen for vaccines is made largely in culture, while hepatitis B vaccine has moved on to the next stage, being made by genetic engineering in yeast. I predicted that synthetic chemistry would eventually take over from culturing, and that is exactly what is happening in the field of vaccines. Interestingly, the first synthetic vaccine to be tested in man is one for the purpose of fertility control: it uses a synthetic peptide corresponding to part of the pregnancy hormone chorionic gonadotrophin.

As for antibodies, 1964 was several years before the invention of monoclonal antibodies, which are now manufactured in large amounts by Celltech and other companies. Enzymes, which I predicted would be manufactured for treatment of metabolic deficiency disease, have been used for exactly that purpose in the treatment of cystic fibrosis.

This last point brings me to my present prediction, which is that gene therapy will take over many of the forms of medical treatment mentioned above, which are at present based on proteins. I refer not just to the rare deficiency diseases, which indeed are already beginning to be treated in this way. Much commoner diseases such as psoriasis or rheumatoid arthritis will probably come to be treated by cytokines. These molecules resemble hormones, except that they act at very short range ("paracrine", as distinct from endocrine). To get them to the right place, for the right time, in the right quantity, and at a reasonable cost can, I believe, only be done by implanting their genes into the right cell. The only alternative, to manipulate the promoters of a patient's own genes, will come, but only later.

Professor Robert Kenedi, Bioengineering Unit, University of Strathclyde.

The predictions for 1984:

Increased understanding of the "modality pattern of operation of the human body as the most complex multivariable self-adaptive control system in existence", leading to improved matching of machine and human operator.

Artificially created atmospheres within huge enclosures designed to serve the physical and psychological needs of the individual in homes, offices and cities.

Prosthetic limbs operated by electric signals generated in appropriately connected muscles when the individual thinks about the movements he or she would like to make.

Artificial joint and tissue implants.

The reality and the future:

I would claim the first item (and only slightly tongue-in-cheek) as an adequately Delphic forecast of the techniques of virtual reality and its rapidly expanding applications. As for the second prediction, it's not quite so Delphic, but perhaps I can permit myself to claim as foretelling the use of just such enclosures in places like present-day leisure park complexes.

As for the third item, this has not obtained because, in my view, the relevant research projects were not rated at a high enough priority to ensure allocation of the necessary resources. However, the fourth item has obtained, but implantable artificial organs, due primarily to development costs, have not. (As an aside, it is intriguing that on 26 August 1994, coincidentally with the writing of these comments, the implantation of an electrically driven heart booster pump of American manufacture - price around 40 000 each - has been announced by Papworth Hospital. Apparently, some 250 of these have already been implanted in the US. A clinical series of some forty such procedures is being planned in this country subject to the resources becoming available.)

Regarding the future, I would designate genetic engineering as the most significant activity of 1994 and beyond. One of its bioengineering applications is the design and construction of biological systems to serve the needs of human tissue and organ implants. The performance of artificial organ replacements for liver and kidney, for example, is greatly enhanced by the addition of genetically engineered human cells, upgrading these artificial organs into bioreactors.

Alongside such commendable advances, there is an aspect of genetic engineering that I find personally highly questionable in both concept and projected outcome. This is the very real possibility in the not-too-distant future of providing animal organ and tissue transplants (for example a pig's kidney, liver, heart, and so on) genetically tailored to be acceptable to human individuals. The societal and individual implications of the formation of such animal/human composites should, I think, be the subject of close public scrutiny now.

Professor Fred Hoyle, cosmologist and independent scientist.

The predictions for 1984:

Closer cooperation will exist between "optical" and "radio" astronomies, leading to identification of fainter radio sources.

Astronomy will pave the way for a major revolution in physics, perhaps by 1984.

The reality and the future:

The prediction of 1964, that optical astronomy and radio astronomy - then seen as very different activities - would become fused into an essentially single line of research has been amply fulfilled. As indeed it has also been for more esoteric activities such as X-ray, gamma-ray and neutrino astronomy. Research workers today do not have the sense of being radically different animals according to the kinds of astronomy they pursue, as was the case in 1964. Everything today belongs to the same platform and astronomy as a whole has become much better for it.

It was also correct in 1964 to foresee that there would be increasing emphasis on cosmology. But I was wrong in my assessment of how the situation in cosmology would develop. I expected most astronomers would see the big bang as a reductio ad absurdum. In consequence, I thought attention would be given to varying the basic "action functions", the sources of the laws of physics, in such a way as to avoid the need for the big bang. Instead, things have gone in exactly the opposite direction. Anything at all, however remote from observation, has become preferred to making a change of the action function. Nevertheless, I still continue to feel that making physics subservient to a particular solution of its own equations, as the big bang theory does, is an absurdity that must disappear sooner or later. So long as alternative possibilities are formulated according to widely accepted physical principles, it seems to me such possibilities, if one or more can be found, must eventually be judged superior to current beliefs.

Professor Meredith Thring, formerly of the Department of Mechanical Engineering, Queen

Mary and Westfield College, London.

The prediction for 1984:

Domestic robots will perform the routine chores of the housewife.

The reality and the future:

Thirty years ago I wrote that science had passed the point of supplying all the basic essentials of life. Now I see that this was far too rosy a picture, because it did not take account of the poverty of millions of people, our heavy use of fossil fuels, expenditure on killing machines and, worst of all, our destruction of the ecosphere.

How can science ensure that my descendants in the year 2100 have the opportunity to earn a decent living by doing a decent job?

All humans will have to have it also, for there can be no long term world stability while the poor look enviously at the rich. Equally a permanent, stable equilibrium with the ecosphere is essential. So we can call the required system Equilibrium Engineering (EE).

In my book, The Engineer's Conscience, I have shown that individual Quality of Life (Q) is low both when consumption is too low or when it is wastefully high. Fortunately, the maximum Q occurs at a level of consumption which could be produced on a permanent basis for eight billion people. This implies that EE is possible, provided it is introduced in time to stop the growth of population above this figure by providing education and secure old age for all.

For example, consider energy. The total world consumption of fossil fuel must be reduced to a third of its present figure, because of the Greenhouse Effect. This implies cutting consumption to the equivalent of about a third of a tonne of oil annually per head, plus renewable energy which does not contribute to the Greenhouse Effect. This amount of fossil fuel would be enough to supply all the essentials of a full life. So how far they will be able to live above the bare minimum depends on how much is invested in permanently renewable energy systems.

Similarly, it is likely that a combination of scientific ideas, such as leaf fractionation and alley cropping, with traditional local wisdom can feed all our descendants.

Can we shift the application of science from "overgrown engineering" to "equilibrium engineering" before it is too late?

Dr Maurice Wilkes, Olivetti Research, Cambridge.

The predictions for 1984:

International network of computers.

Routine use of computer simulation in economic policy making and in understanding how genetic codes work.

The reality and the future:

I was right on most counts and 100 per cent right about the great growth in computer networks. However, I was wholly adrift when I assumed that we would be for ever restricted to narrow bandwidths. That is, to sending information at very slow rates. I did not foresee that the development of optical fibres would change the situation dramatically. Neither, of course, did anyone else, since in 1964 optical fibres were not even a twinkle in an inventor's eye.

Bandwidth is all set to change from being a commodity that is scarce and expensive to being one that is plentiful and cheap. An exactly similar thing happened to computer hardware when minicomputers and mainframes began to give way to PCs and workstations that could be bought at a fraction of the cost. What made this possible was the success of the semiconductor industry in doubling, and continuing to double, the speed of silicon chips every two years. The effect was to bring about a serious destabilisation of the older sections of the computer industry.

We should know by 2004 what effect fibre optics will have on the telecommunications industry. Major changes will occur, although I do not expect the sort of destabilisation we have seen in the computer industry. On the other hand, the broadcasting industry may be radically affected. According to one scenario, instead of having to catch your television entertainment at the time it is put out, you may be able to choose from a menu of goodies available, and dial in for what you want when you want it.

Professor Ian Fells, Department of Chemical and Process Engineering, University of Newcastle upon Tyne.

The predictions for 1984:

Cars powered by fuel cells driving electric motors built into the wheel hubs, and pollution-free exhaust.

Domestic fuel cells running off piped hydrocarbon gases in each house, promoted by a growing supply of natural gas.

Biochemical fuel cells which could be used to operate heart pacemakers.

The reality and the future:

In 1964 I emphasised dissatisfaction with the low efficiency of combustion or nuclear fission process into electricity and pointed to the use of topping cycles for improving large-scale electricity generation (500 megawatt) and fuel cells for small scale (10 kilowatt) generation. The systems, I expected, would raise conversion efficiencies from less than 35 per cent to over 60 per cent.

As far as large scale generation is concerned, the topping cycle turned out to be the gas turbine, not the magneto-hydrodynamic system, giving combined cycle gas turbine steam turbine cycles generation efficiencies now approaching 60 per cent.

I also hinted that improvement in the efficiencies of combustion-generated electricity might cause us to reappraise the future of nuclear power. On a small scale, prototype fuel cell-powered cars are now running in California, encouraged by legislation postulating 10 per cent zero emission vehicles by 2003. So my predictions were not far off the mark, although progress has been slower than I had hoped; engineers are always optimistic about technological improvement.

I also pointed to the increased availability and use of natural gas; this in 1964 when natural gas had not even been discovered in the North Sea. Natural gas is the new, major player in the energy league and whilst we do not yet have domestic gas-fired fuel cell systems as I suggested, we do have highly efficient local combined heat and power schemes.

Looking to the long-term energy future and pondering on what changes we can anticipate to compare with Faraday's discovery of electromagnetic induction in 1831, maybe before the end of the next century we will have unravelled the mysteries of gravitation and tamed "black holes" to provide a new source of electricity for the next millennium or so.

Dr Fred Singer, director of the Science and Environmental Policy Project, Washington DC.

The predictions for 1984:

Nuclear-powered satellites orbiting the Earth, predicting weather conditions and providing information about Earth, oceans and space.

By 2000, we will be able to manipulate climate.

The reality and the future:

It's fun to look back thirty years and see how predictions I made in 1964 have turned out. The record is decidedly mixed: a B+ for the technical part; a C- for the institutional part.

In 1964, I had just finished a tour of duty as the first director of the US operational weather satellite system (now part of NOAA, the National Oceanographic and Atmospheric Administration) and was full of optimism that the rate of advancement would continue. Well, most of the observational capabilities I looked for have been achieved, covering the electromagnetic spectrum with high resolution and allowing just about all of the applications I had envisioned: ocean, surface, atmospheric layers, and much of space beyond.

But the Pentagon threw me a curve; they set up a separate satellite system for navigation, GPS (Global Positioning System). But as a consolation, the military MetSat system is finally being integrated with the civilian weather satellites. Maybe GPS will follow and combine into just one satellite system.

We are still a long way from an international system, however, such as we have for communications. And we are even further from efforts of climate modification - although meteorological satellites are the prototype of the EOS (Earth Observing System) that is supposed to keep track of any inadvertent climate modification that might be brought about by human activities.

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